Enabling Regional Climate Model Evaluation: A Critical Use of Observations for Establishing Core NCA Capabilities

Principal Investigator

Duane Waliser, JPL

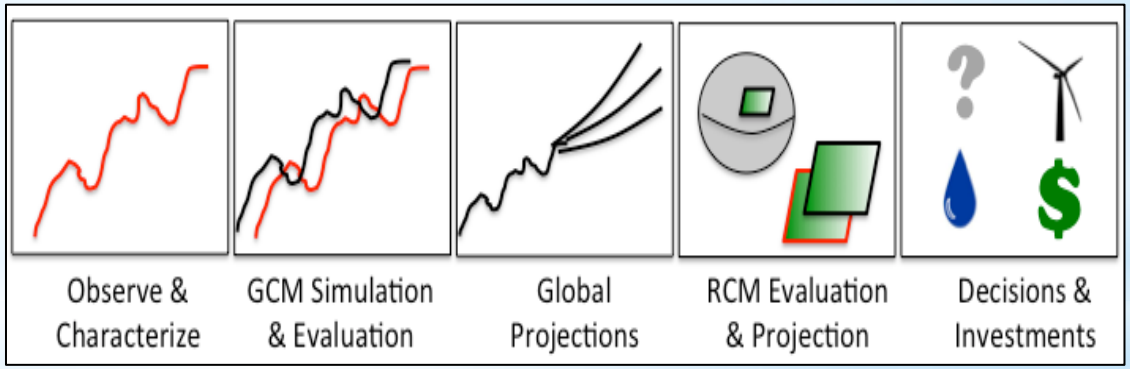
Co-Investigators

Linda Mearns, NCAR

Chris Mattmann, JPL

Jinwon Kim, UCLA

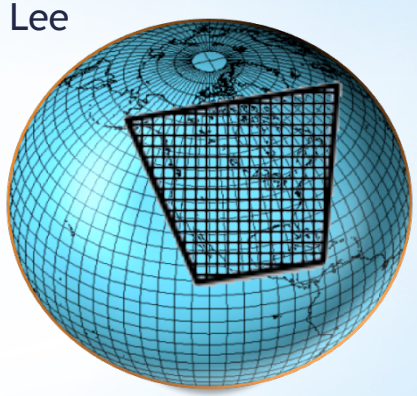
+ 2 new, partially supported postdocs: Paul Loikith & Huikyo Lee



Response to: **NASA Center's Call for Proposals**

To Support The **National Climate Assessment**

PI Telecon : November 20, 2012



Enabling Regional Climate Model Evaluation:
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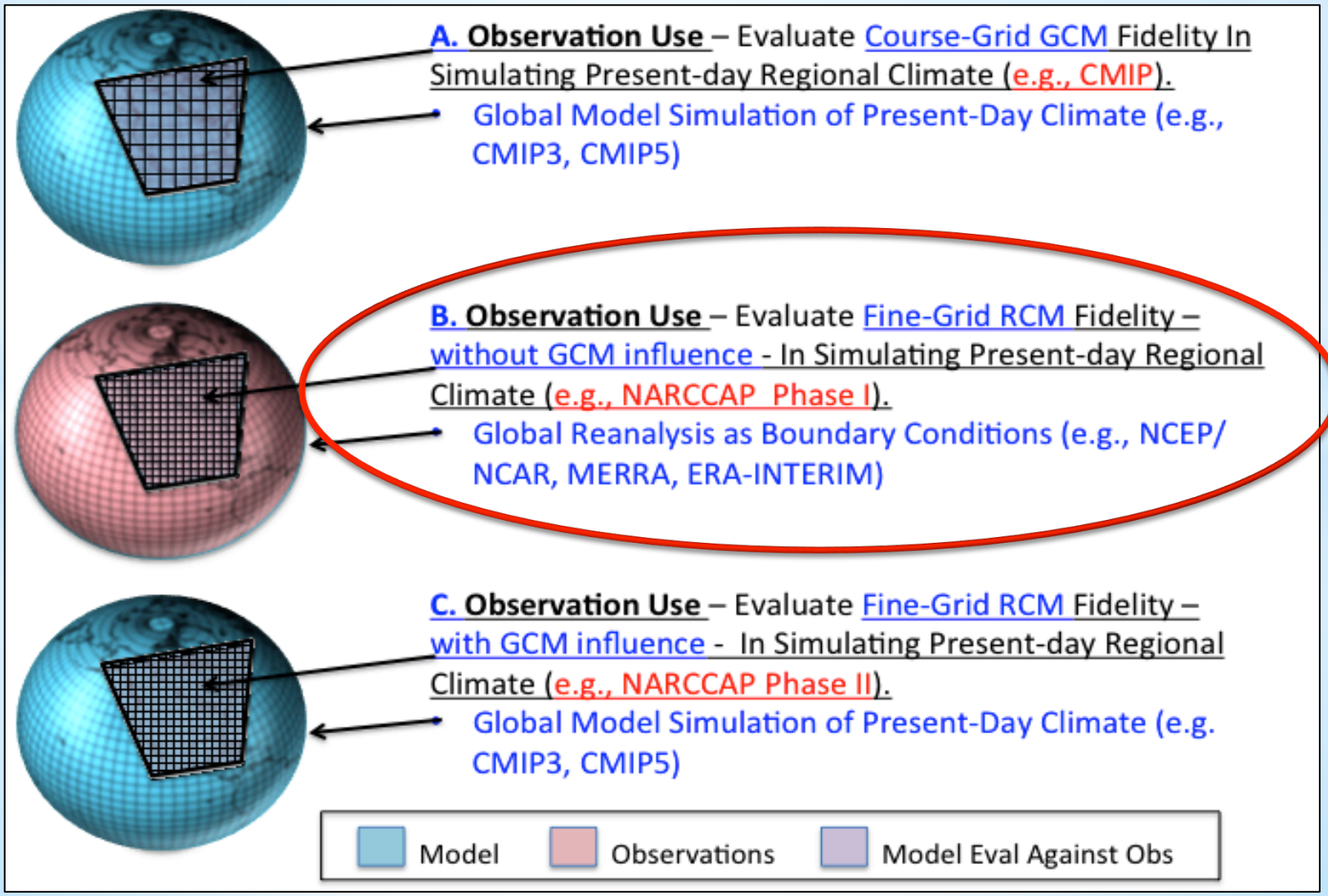
- Global Climate Models (GCMs) provide the only quantitative, physically-based means for predicting climate change.
- Regional climate models (RCMs) are a key tool to downscale the global predictions for characterizing and quantifying climate change impacts on scales relevant to decision-support and climate assessment activities (e.g. NCA).
- It is imperative that GCMs and RCMs are evaluated against observations so that their strengths and weaknesses can be quantified and model shortcomings can be improved.
- Systematic evaluation studies of GCMs have been undertaken for some time (e.g., AMIP, CMIP, CFMIP), however there has been less attention/consideration made to systematic evaluation of RCMs.
- NASA can provide critical and unique observational resources and technological leadership to facilitate RCM evaluation and thus make key contributions to the NCA process.

Using NASA Observations for model evaluation relevant to the NCA



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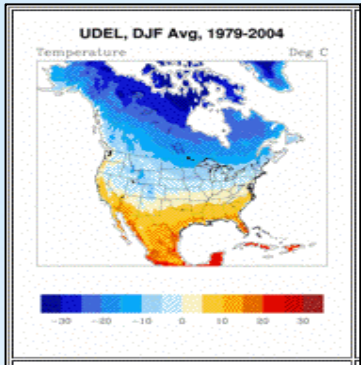
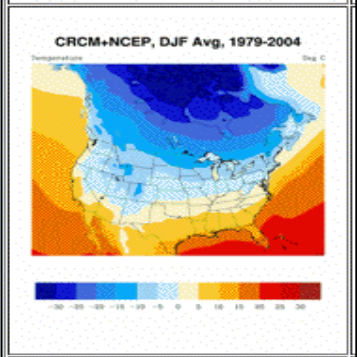
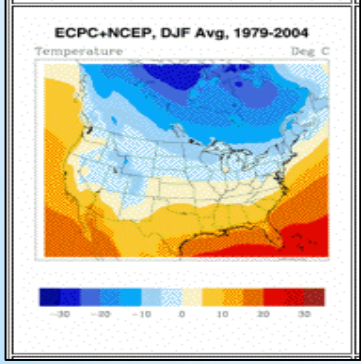
NARCCAP

North American Regional Climate Change Assessment Program







Regional Models

Model	Aliases	Modeling Group	Full Name
CRCM	MRCC	OURANOS / UQAM	Canadian Regional Climate Model / le Modèle Régional Canadien du Climat
ECPC	RSM	UC San Diego / Scripps	Experimental Climate Prediction Center Regional Spectral Model
HRM3	PRECIS, HadRM3	Hadley Centre	Hadley Regional Model 3 / Providing REgional Climates for Impact Studies
MM5I	MM5, MM5P*	Iowa State University	MM5 - PSU/NCAR mesoscale model
RCM3	RegCM3	UC Santa Cruz	Regional Climate Model version 3
WRFP	WRF	Pacific Northwest Nat'l Lab	Weather Research & Forecasting model

Drivers

Driver	Full Name	Ensemble Member Used
CCSM	Community Climate System Model	b30.030e (ctl), b30.042e (fut)
CGCM3	Third Generation Coupled Global Climate Model	CGCM #4
GFDL	Geophysical Fluid Dynamics Laboratory GCM	20C3M, run2; sresa2, run1
HadCM3	Hadley Centre Coupled Model, version 3	Custom run for NARCCAP
NCEP	NCEP/DOE AMIP-II Reanalysis	N/A

RCM / GCM combinations

	Phase I	Phase II			
	NCEP	GFDL	CGCM3	HADCM3	CCSM
CRCM	X		1		2
ECPC	X	1		2	
HRM3	X	2		1	
MM5I	X			2	1
RCM3	X	1	2		
WRFP	X		2		1
timeslice		X			X

1: First pairing to be run
2: Second pairing to be run

SPONSORS

NCAR

NOAA NSF

OURANOS

NARCCAP is the North America Regional Climate Change Assessment Program (PI: L. Mearns, NCAR).

Several RCMs downscaling future climate change projections from GCMs.

RCM performance needs to be characterized against observations using present-day simulations.

NARRCAP is the U.S./N.A. contribution to CORDEX.

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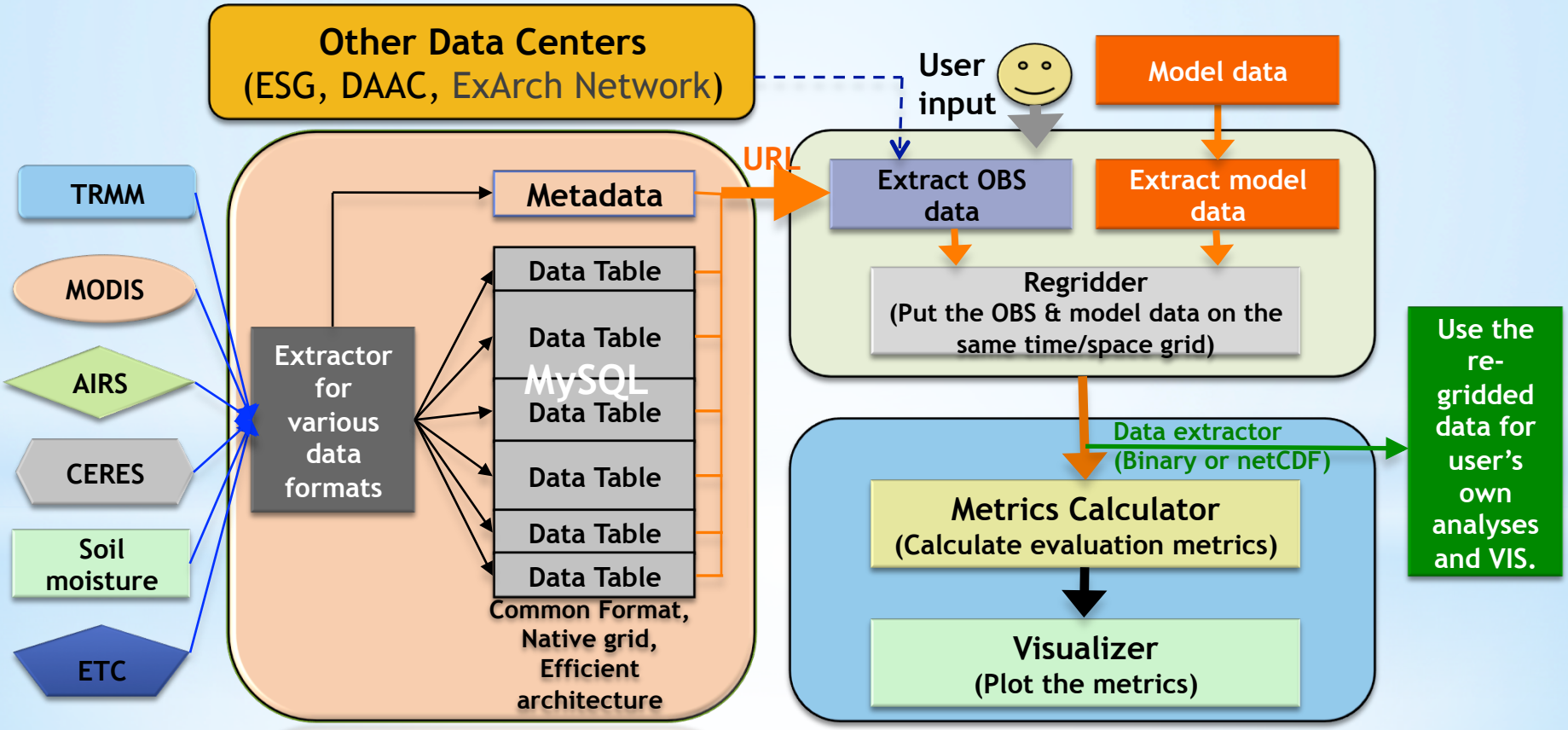
RCMES v2.0 – High-Level Architecture



Raw Data:
Various sources, formats, Resolutions, Coverage

RCMED
(Regional Climate Model Evaluation Database)
A large scalable database to store data from variety of sources in a common format

RCMET
(Regional Climate Model Evaluation Tool)
A library of codes for extracting data from RCMED and model and for calculating evaluation metrics

Ingest obs/models, re-gridding, calculate metrics (e.g, bias, RMSE, correlation, significance, PDFs), and visualize results (e.g., contour, time series, Taylor).

RCMES
High-level technical architecture

AVAILABLE

- AIRS gridded daily 3D temperature and water vapor
- TRMM 3B42 3-hourly gridded daily precipitation
- ERA-Interim 6-hourly surface temperature & dewpoint, 3D temperature & geopotential
- NCEP daily Unified Rain gauge Database (URD), 0.25º resolution
- Satellite-based Snow Water Equivalent (SWE) assimilation data (Sierra Nevada)
- MODIS daily Cloud fraction and snow cover
- Climate Research Units (CRU) monthly precipitation and temperature (Tavg, Tmin, Tmax) at 0.5º resolution.
- MERRA- Sea-level pressure, surface pressure
- CERES radiation – Surface and Top of the atmosphere
- University of Delaware precipitation and temperature analysis

FUTURE

- CloudSat atmospheric ice and liquid, Satellite-based snow (Himalayas), ISCCP cloud fraction, MERRA (water vapor, surface and pressure-level variables), Sea-level heights, Fine-scale SST, etc.

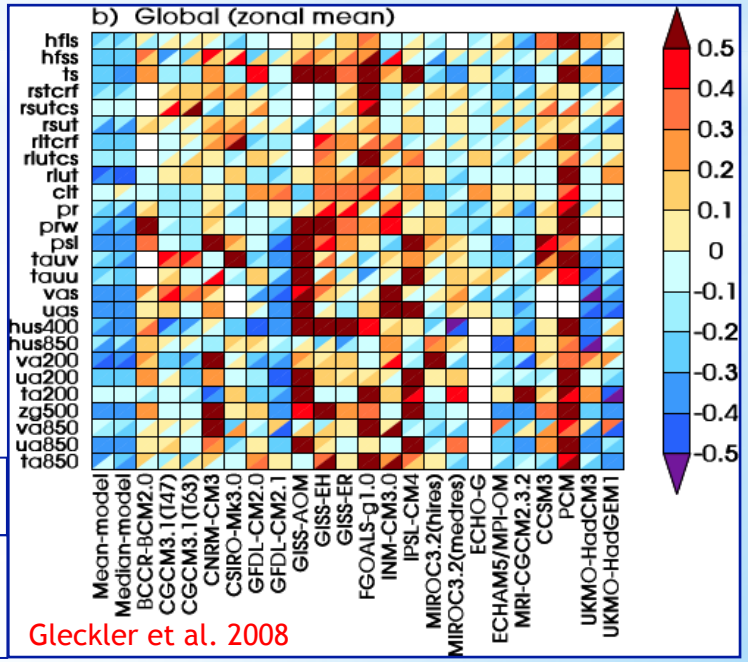
Ingest obs/models, re-gridding, calculate metrics (e.g, bias, RMSE, correlation, significance, PDFs), and visualize results (e.g., contour, time series, Taylor).

This activity includes three tasks:

I) Tailoring RCMES for application to the NCA. (e.g. data sets, metrics, visualization, GUI

II) Systematic application of observations to evaluate NARCCAP RCM and CMIP GCM simulations over the U.S./N. America.

III) Overall incorporation of model evaluation/assessment results and RCMES infrastructure into the near- and long-term NCA process.



GOAL

Observation-based model performance metrics for modeling regional climate.

Progress Tailoring RCMES

* RCMED - database
  * Additional data sets added – see previous slide
  * Exploring the use of MongoDB and other advanced DB architectures.

* RCMET - toolkit
  * Metrics calculation: Bias, RMSE, pattern and temporal correlations, PDFs, etc
  * Visualization using contour maps, Taylor and Portrait diagrams, x-y line plots, etc.
  * Constructed Virtual Box and VMWare images for easy deployment
  * Delivered RCMET 2.0 multi-model analysis version of toolkit to CORDEX South Asia

* Public Website/Portal Release
  * http://rcmes.jpl.nasa.gov

SYNERGISTIC INTERACTIONS

* North American Regional Climate Change Assessment Project (NARCCAP) = CORDEX N. America, funded via NCA.
  * Paper submitted, under revision.
* CORDEX-Africa
  * In collaboration with University of Cape Town, Republic of South Africa, and Swedish Meteorological and Hydrological Institute (SMHI), Sweden. Partial support from CKDN (see below).
* CORDEX-South Asia
  * In collaboration with Indian Institute of Tropical Meteorology, India. Hosted lead, Dr. Sanjay at JPL. Had science and IT representation at recent October 2012 CORDEX S. Asia meeting.
  * Installed RCMES-VM version at IITM for testing with CORDEX-South Asia data.
* EXPLORING USE OF RCMES with CORDEX ARCTIC, E. Asia.
  * Attended 1st CORDEX Arctic meeting in March, 2012.
  * Attended (1st and) 2nd CORDEX E. Asia meeting in October, 2012.
* Climate & Knowledge Development Network (CKDN; http://cdkn.org/)
  * Synergistic activities with B. Hewitson (PI) & U. of Cape Town (UCT), and Roger Street (Oxford University)
  * Evaluating RCMES and its use in climate training: 1st user lab in April 2012 in Dakar
* Kim Whitehall – Howard University/Prof. G. Jenkins Advisor
  * Incorporating RCMES into her PhD studies on regional Climate Modeling (Africa)
  * Visited JPL during summer 2012.
  * Developed idea for WMO Bulletin article – see later slide.
* Melanie Cooke – University of Toronto/Prof. Paul Kushnir
  * Incorporating RCMES into her PhD studies on regional Climate Modeling (Arctic)
  * Visited JPL during summer 2012.
* Rama Rao M. V. S. – IITM, India/J. Sanjay
  * Applying RCMES to CORDEX-S. Asia as model evaluation/data handling tool.

NARCCAP Multi-decadal Hindcast Evaluation Results - Limited/Preliminary

Figure. The conterminous US domain. The boxes indicate the locations of the 14 subregions.

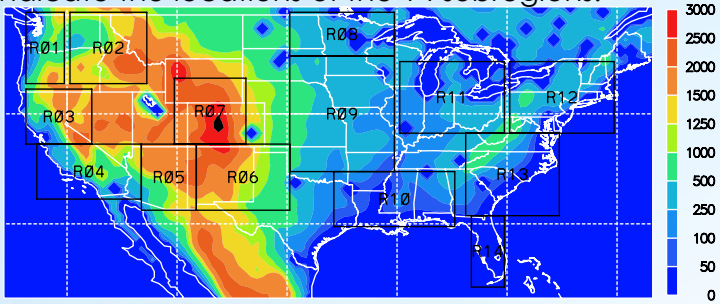
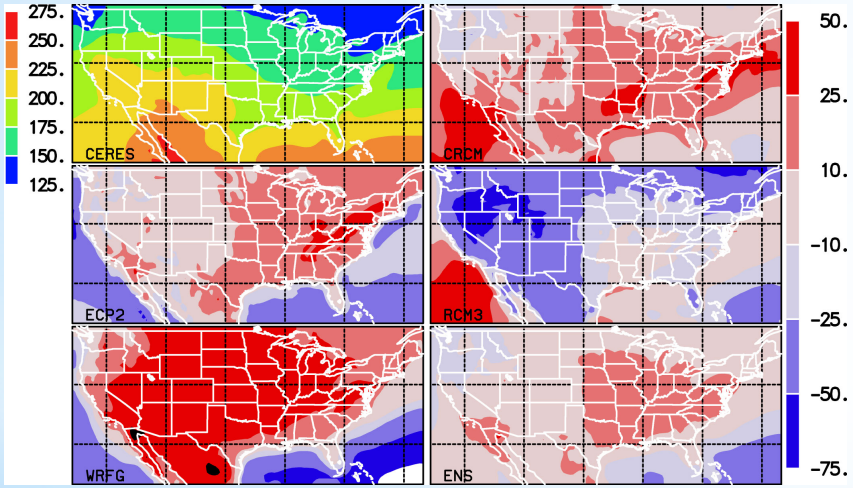


Figure. RCM biases in surface insolation against CERES



- The monthly-mean time series of the daily-mean **surface air temperatures and precipitation** over the conterminous US region from **five RCMs** (Table 1) that have participated in the **NARCCAP hindcast experiment** have been evaluated against the CRU data for the 24-year period 1980-2003.
- The RCM simulations, mostly at 50km horizontal resolutions, are interpolated onto a common grid nest of 0.5-deg horizontal resolution for analysis, evaluation, and inter-comparison (Figure).
- Fourteen sub-regions (as depicted in the figures and table) are selected for closer examinations of model performances in various regions of interests (Table 2).
- Kim, J., D.E. Waliser, C.A. Mattmann, L.O. Mearns, C.E. Goodale, A.F. Hart, D.J. Crichton, and S. McGinnis, 2012: Evaluations of the surface air temperature, precipitation, and insolation over the conterminous U.S. in the NARCCAP multi-RCM hindcast experiments using RCMES. J. Climate, under minor revision.

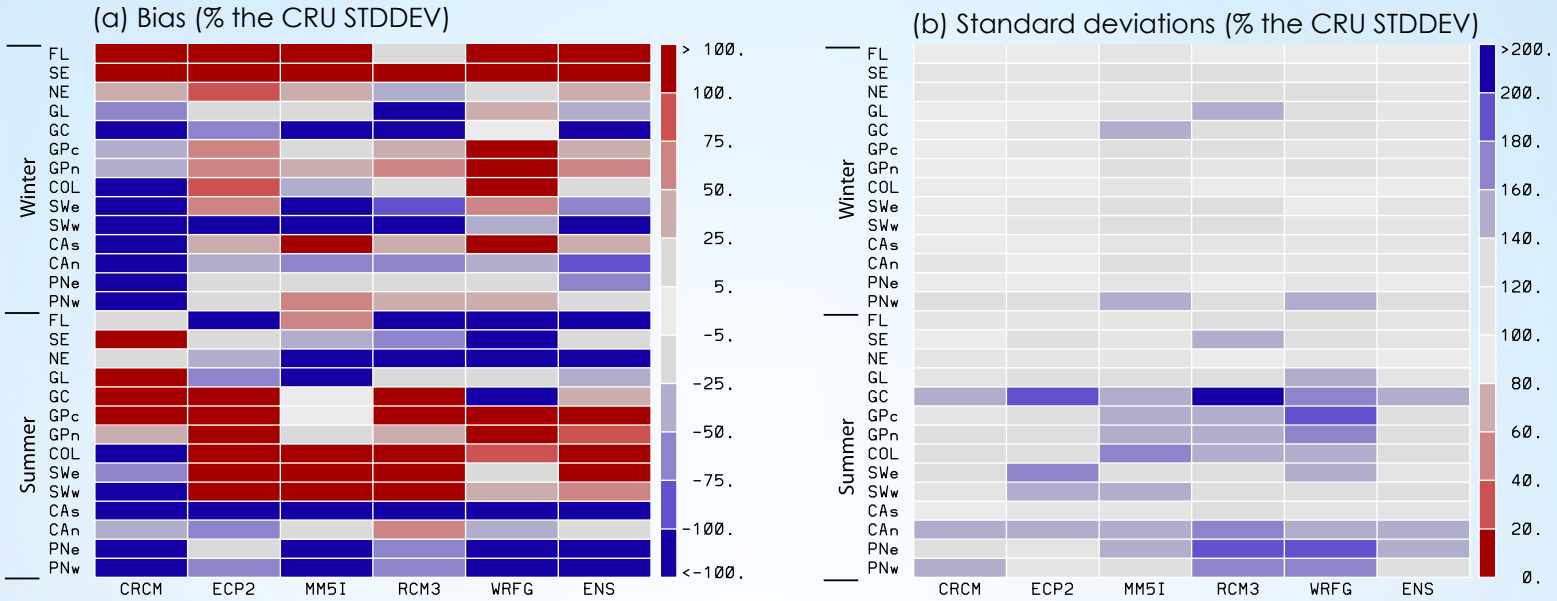
Table 2. The relationship between precip & insolation biases.

Model	Land-mean bias - Precipitation (mm/d)	Land-mean bias - Insolation (Wm^{-2})	Bias pattern Correlation
CRCM	0.33	10.2	-0.47
ECP2	0.41	9.0	-0.28
RCM3	0.54	-29.9	-0.50
WRFG	-0.08	30.4	-0.18
ENS	0.25	4.9	-0.62

Table 1. The RCMs evaluated in this study.

Model ID	Model Name
M01	CRCM (Canadian Regional Climate Model)
M02	ECP2 (NCEP Regional Spectral Model)
M03	MM5I (MM5 – run by Iowa State Univ.)
M04	RCM3
M05	WRFG (WRF – run by PNNL)
ENS	Model Ensemble (Uniform weighting)

Seasonal surface air temperature climatology
Bias and interannual variability



- The simulated summer (JJA) and winter (DJF) surface air temperatures in the 14 sub-regions are evaluated against the CRU analysis data.
  - Standard deviation is used as the indicator for the magnitude of interannual variability.
  - Model bias and standard deviation are normalized by the standard deviation of the CRU data.
- Mean biases vary, quite systematically, according to geography and season
  - Warm biases in the Great Plains area for both summer and winter
  - Cold biases in the Pacific, Gulf, and Atlantic coast regions in summer
  - Warm biases in the Atlantic coast (NE and SE), Florida (FL) and northern California (CAn) during winter.
- All models reasonably simulated the interannual variability of the winter temperatures in almost all regions.
  - The interannual variations in the summertime surface air temperature are generally overestimated by almost all models in almost all regions.
- The model ensemble is consistently among the best performers for all seasons, regions, and metrics.

RCMES article in the latest issue of the WMO Bulletin highlighting its potential role in WMO's new Global Framework for Climate Services

Kim Whitehall is a Howard University graduate student. She spent the summer at JPL learning & contributing to RCMES.

Building Model Evaluation and Decision Support Capacity for CORDEX

by Kim Whitehall[1,3], Chris Mattmann[1,3,4], Duane Waliser[1,2], Jinwon Kim[2], Cameron Goodale[1], Andrew Hart[1], Paul Ramirez[1], Paul Zimdars[1], Dan Crichton[1], Gregory Jenkins[5], Colin Jones[5], Ghassam Asrar[6], Bruce Hewitson[7]

Summary and Plans

* NARCCAP Model Evaluation Study

  Kim, J., D.E. Waliser, C.A. Mattmann, L.O. Mearns, C.E. Goodale, A.F. Hart, D.J. Crichton, and S. McGinnis, 2012: Evaluations of the surface air temperature, precipitation, and insolation over the conterminous U.S. in the NARCCAP multi-RCM hindcast experiments using RCMES. J. Climate, under minor revision.

  Related papers

  Kim, J., D. E. Waliser, C. A. Mattmann, C. E. Goodale, A. F. Hart, P. A. Zimdars, D. J. Crichton, C. Jones, G. Nikulin, B. Hewitson, C. Jack, C. Lennard, and A. Favre (2012), Evaluation of the CORDEX-Africa multi-RCM hindcast experiment using the Regional Climate Model Evaluation System (RCMES), Climate Dynamics, Submitted

  Whitehall, K., C. Mattmann, D. Waliser, J. Kim, C. Goodale, A. Hart, P. Ramirez, P. Zimdars, D. Crichton, G. Jenkins, C. Jones, G. Asrar, and B. Hewitson, 2012: Building model evaluation and decision support capacity for CORDEX. *WMO Bulletin*, **61**, 29-34.

  Additional IT papers and CMIP5 sierra snowpack study.

* RCMES development (IT team)
  - RCMED database – inclusion of additional satellite and other datasets
  - RCMET toolkit – additional metrics
  - Improved user interface
  - Improved and varied portability – moving toward more community use (e.g. CORDEX)
  - Website developed/released.

* Formal NCA Inputs (+ formal reviews of IPCC Ch. 9 Model Evaluation)

  Waliser, D., J. Kim, C. Mattmann, and L. Mearns, 2012: Regional climate model evaluation: A critical component of the scientific basis and decision support elements of the NCA. *Tech. input for consideration to the 2013 Us National Climate Assessment*, 19pp.

  Mattmann, C., D. Waliser, and J. Kim, 2012: Developing the technical capabilities of a regional climate model evaluation system to support the NCA process. *Tech. input for consideration to the 2013 Us National Climate Assessment*, 6pp.

* Community interactions & collaborations – CORDEX Africa, S.Asia, E. Asia, Arctic
* Hired 2 (partially supported postdocs) – science application & database/metric development
* Near-term plan
  - RCMED & RCMET Expansion
  - Improved user Interface and portability
  - Regional evaluations of CMIP5
  - Cultivate related CORDEX opportunities to gain insight into user and decision-support needs.